Announcements

- Homework for tomorrow…

  Ch. 22, CQ 3, Probs. 2, 4, & 8

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 22

Wave Optics

(Light and Optics &

The Interference of Light)

Last time…

- *Frequency*, f, and *period*, T…

$$f = \frac{1}{T}$$

- The *wave speed* is…

$$v = \lambda f$$

- The *index of refraction* is…

$$n \equiv \frac{c}{v}$$

- The *wavelength* in a material is…

$$\lambda_{mat} = \frac{\lambda_{vac}}{n}$$

i.e. 20.8
Light traveling through glass

Orange light with a wavelength of 600 nm is incident upon a 1.00 mm thick glass microscope slide.

a. What is the light speed in the glass?

b. How many wavelengths of the light are inside the slide?

$n = 1.5 = \frac{c}{v}$

$v = \frac{c}{1.5} = 2.0 \times 10^{8}\ m/s$

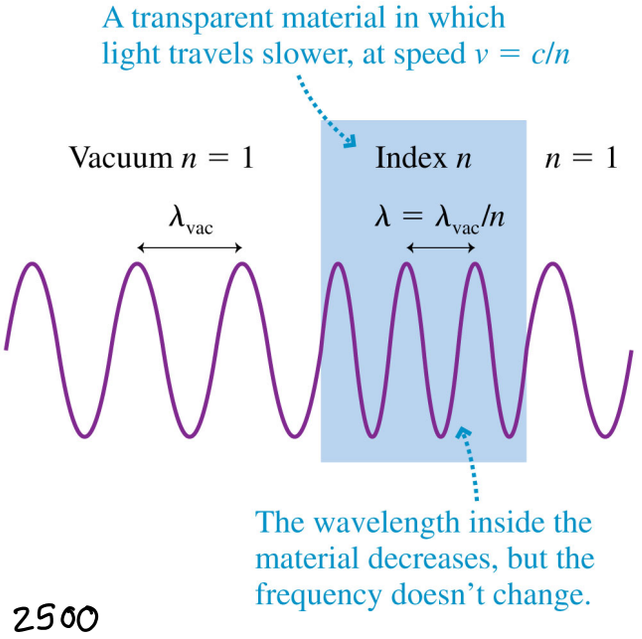
$\lambda_{mat} = \frac{\lambda_{vac}}{n} = \frac{6.00 \times 10^{-7}\ m}{1.5}$

$400 \times 10^{-7}\ m = 400\ nm$

$N\lambda = d$

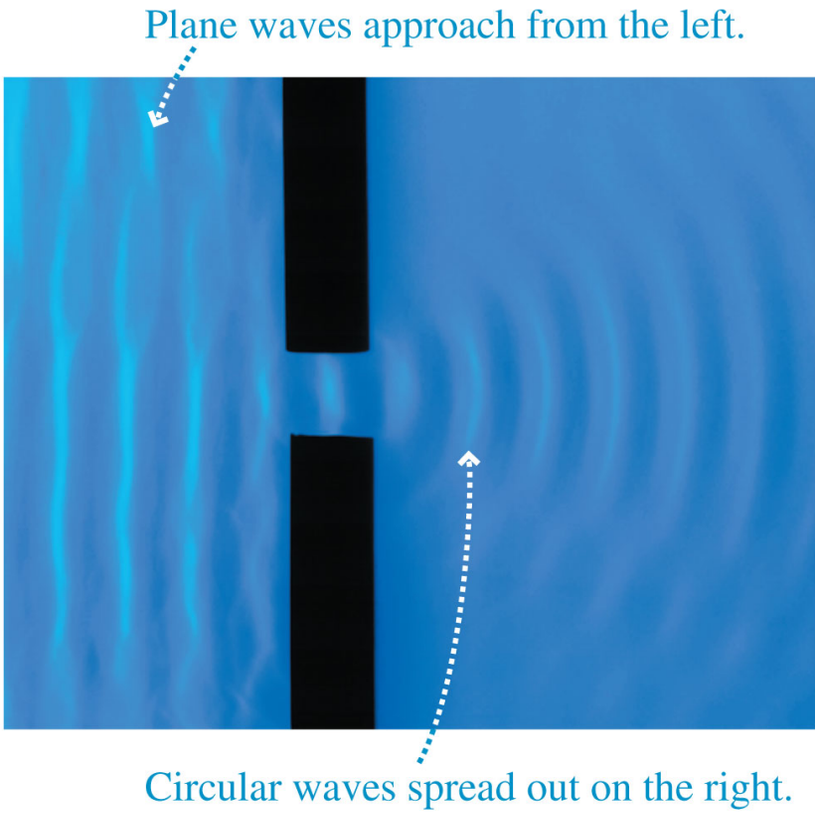
$N = \frac{d}{\lambda} = \frac{1.00 \times 10^{-3}\ m}{4.00 \times 10^{-7}\ m} = 2500$

$N = 2500$

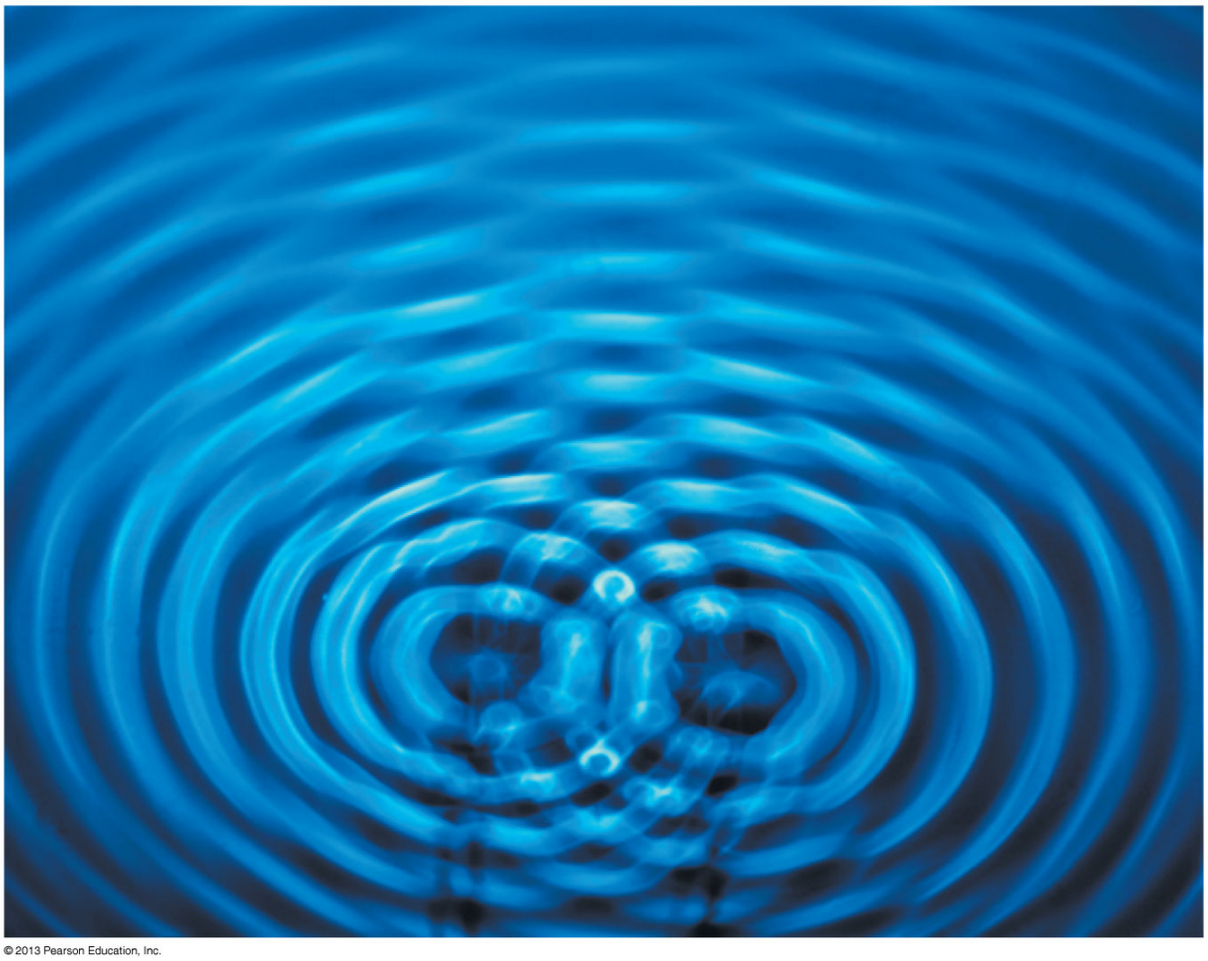


Diffraction of H_2O Waves…

- A H_2O wave, after passing through an opening, *spreads out* to fill the space behind the opening.
- *Diffraction* = spreading out of waves.
- All waves experience *diffraction*.



Interference…

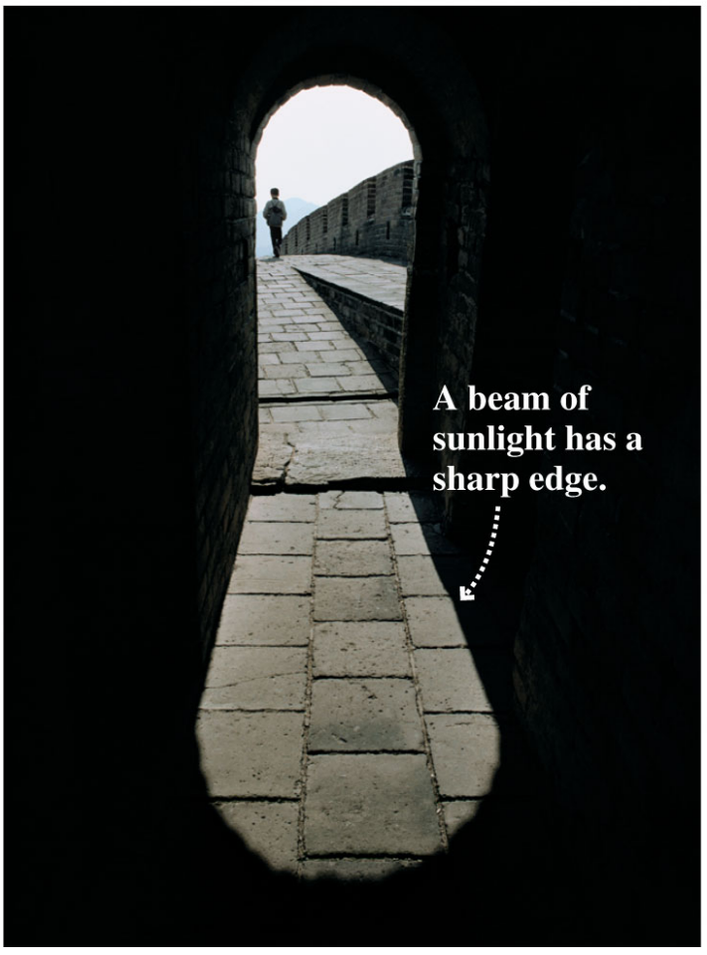


Diffraction of Sunlight?

- Unlike a H_2O wave, when light passes through a a large opening, it makes a *sharp-edged* shadow.

- This lack of noticeable diffraction means that *if* light is a wave, the wavelength must be *very small*.

- So, is light a wave or a particle?



22.1: Light and Optics

Does light consist *of waves* or *of particles*?

Isaac Newton (1660)

- does not witness *diffraction* of sunlight.
- concludes that light must consist of *very small, light, fast particles* that he calls *corpuscles*.

Thomas Young (1801)

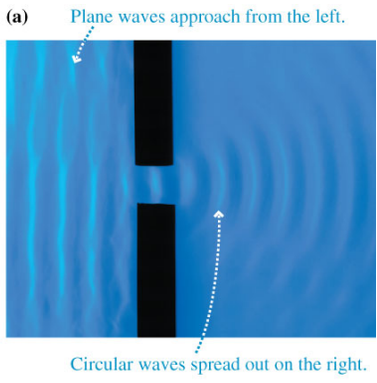
- produces *interference* between two waves of light.
- concludes that light consists of *waves* (but *WHAT* is waving?).

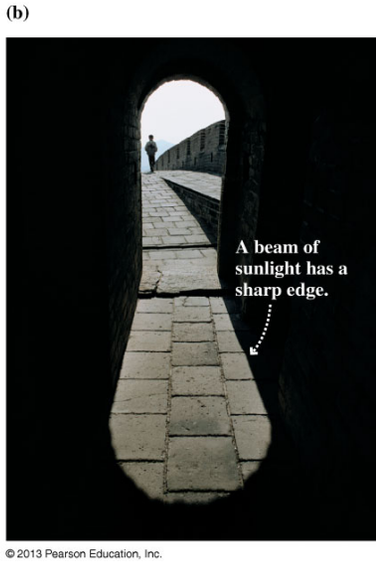
James Maxwell (1860)

- Maxwell equations predict EM *waves* that travel at a speed *c*!

Albert Einstein (1905)

- Photoelectric effect
- Light consists of *photons* w/ BOTH wave-like & particle-like properties!





Models of Light…

Wave Model:

- Under many circumstances, light exhibits the same behavior as sound or water waves.
- The study of light as a wave is called *wave optics*.

Ray Model:

- The properties of prisms, mirrors, and lenses are best understood in terms of *light rays*.
- The ray model is the basis of *ray optics*.

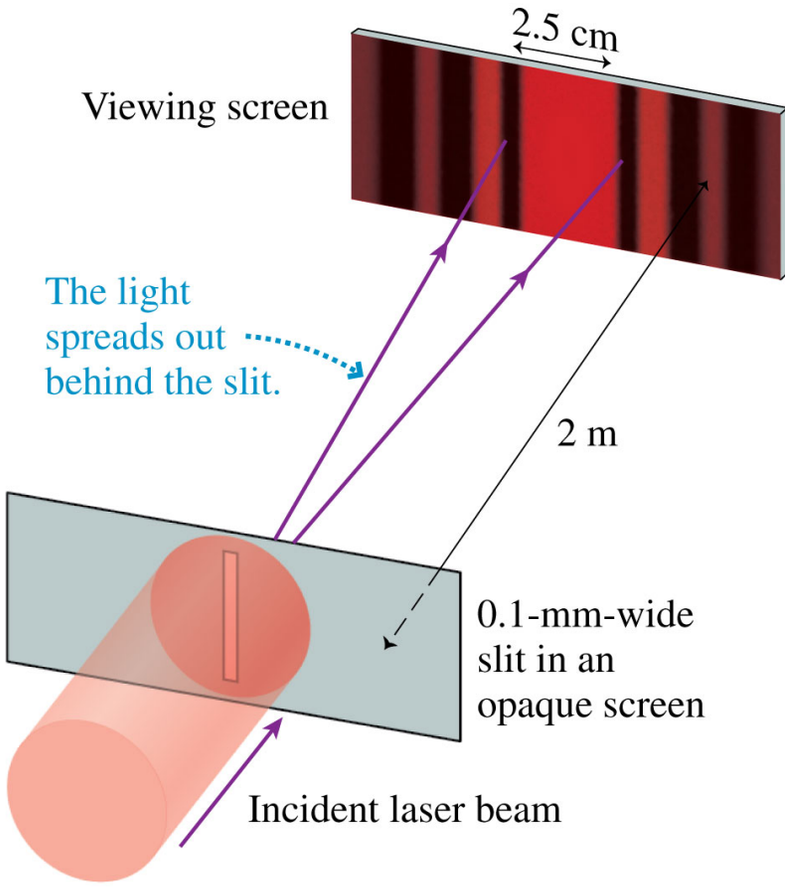
Photon Model:

- In the quantum world, light behaves like NEITHER a wave NOR a particle.
- Instead, light consists of *photons* that have both *wave-like* and *particle-like* properties!
- This is the *quantum theory* of light.

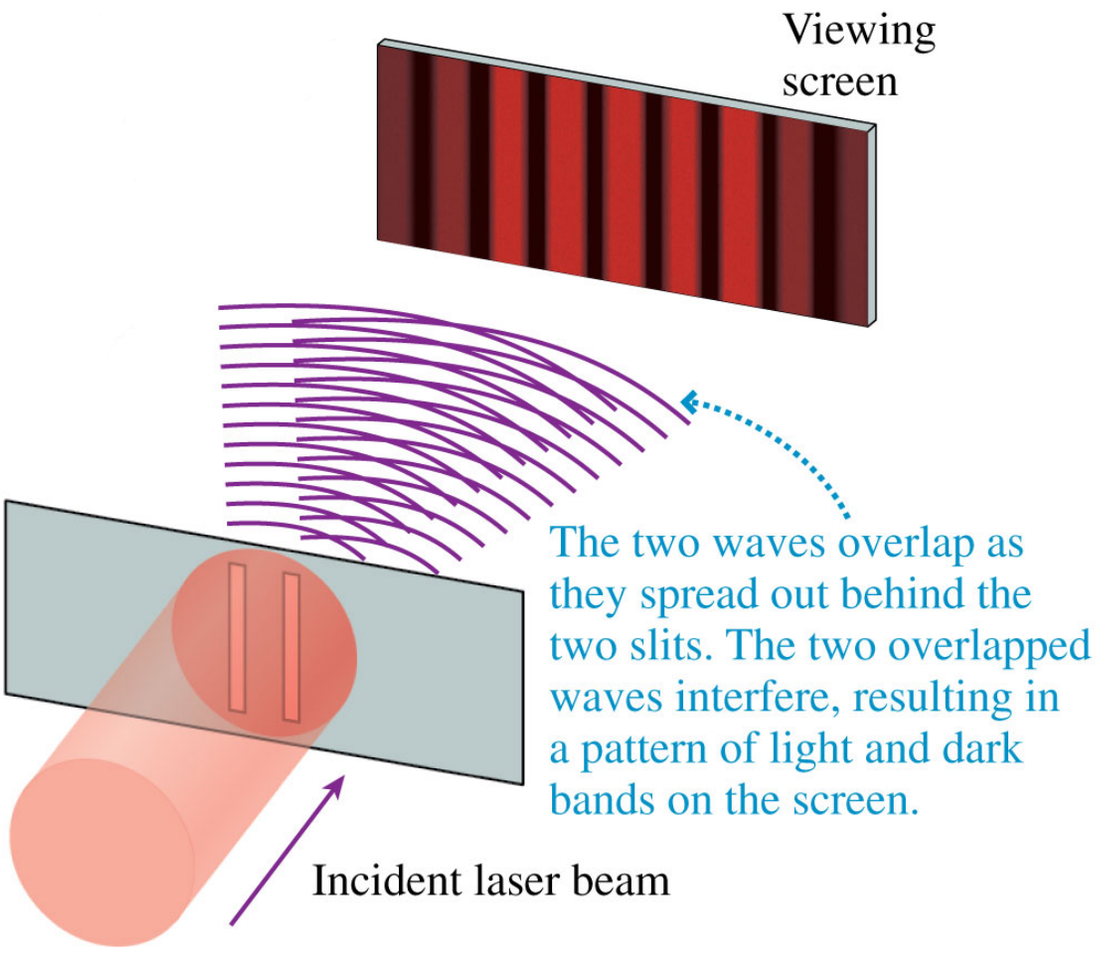
22.2:
The Interference of Light

- When light passes through a *very* small opening, it *spreads* out.

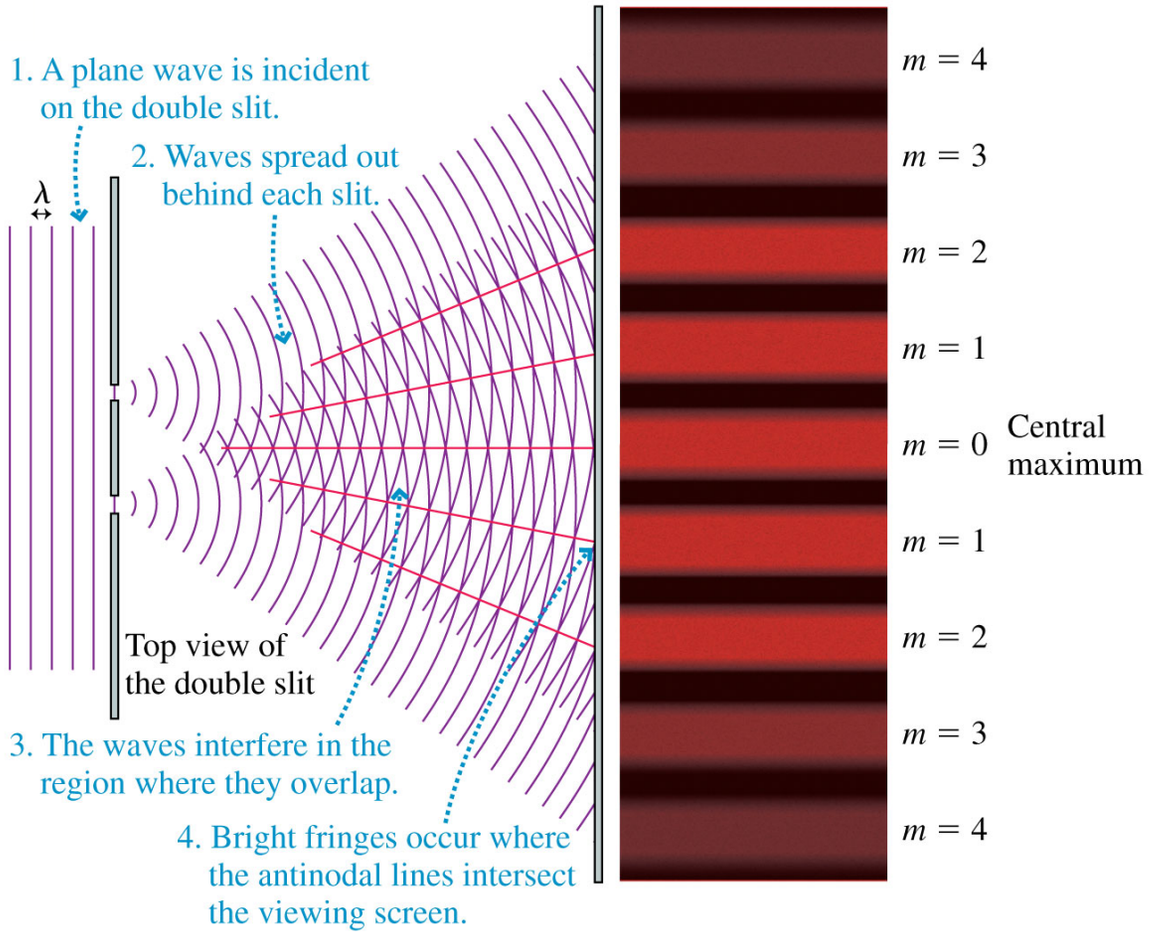
- Diffraction of light is observable IF the hole is *sufficiently small*.



Young's Double-Slit Experiment…

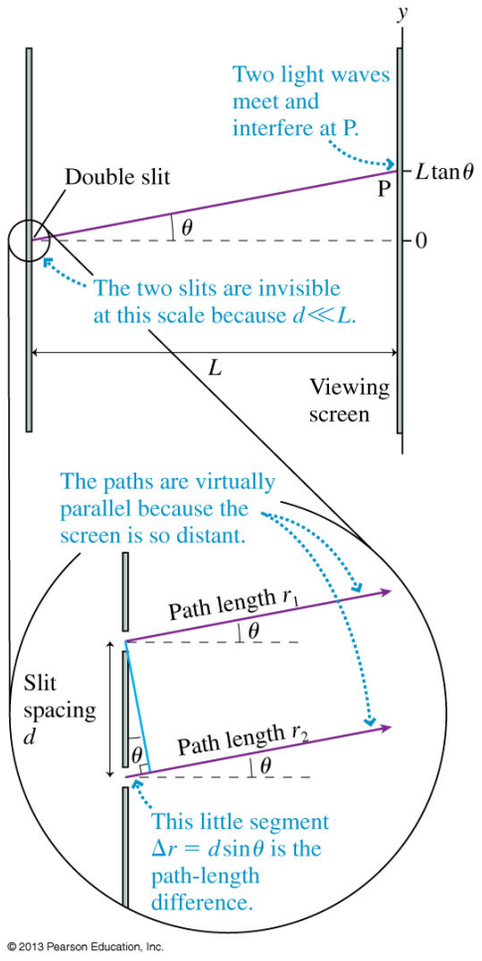


Young's Double-Slit Experiment...

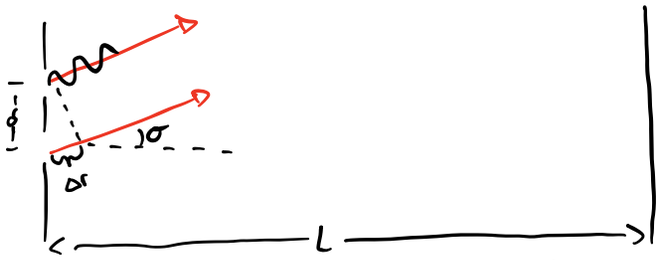


Analyzing Double-Slit Interference…

What are the *angular positions* of the *bright fringes* in the interference pattern?



Where does the m^{th} *bright fringe* occur?



$\Delta r = d\sin\theta = r_2 - r_1$

Constructive interference

$\Delta r = m\lambda$

$m\lambda = d\sin\theta$

$m\lambda = d\theta_m$

$\theta = \frac{m\lambda}{d}$

θ is very small $L \ll d$

$\tan\theta = \frac{y}{L}$

$\theta = \frac{y}{L} \therefore \left[y_m = L\theta_m = \frac{m\lambda L}{d} \right]$

$\tan\theta = \theta$

Analyzing Double-Slit Interference…

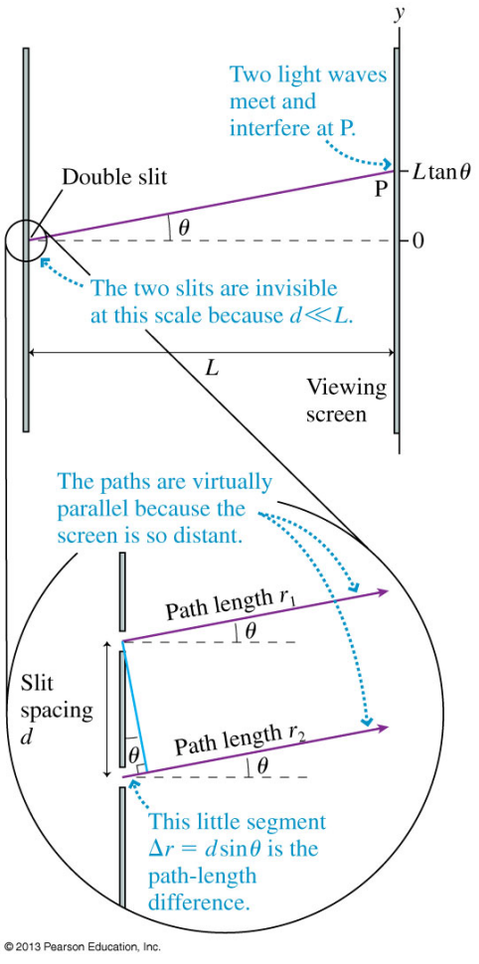
What are the *angular positions* of the *bright fringes* in the interference pattern?

$$\theta_m = m\frac{\lambda}{d} \quad , \quad m = 0, 1, 2, 3, \ldots$$

in *radians*!

Where does the m^{th} *bright fringe* occur?

$$y_m = \frac{m\lambda L}{d} \quad , \quad m = 0, 1, 2, 3, \ldots$$



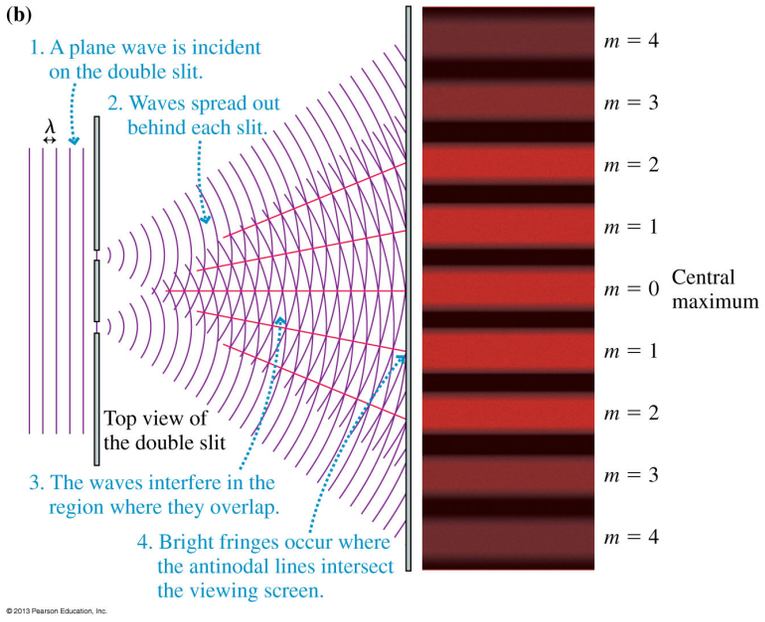
Analyzing Double-Slit Interference…

What is the *fringe spacing* between the m fringe and the m+1 fringe?

$$\Delta y = y_{m+1} - y_m$$

$$= (m+1)\frac{\lambda L}{d} - \frac{m\lambda L}{d}$$

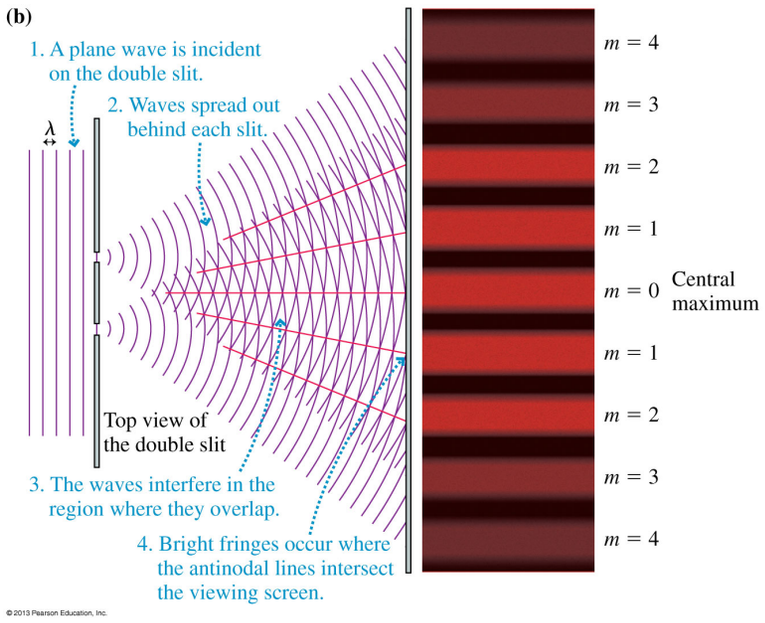
$$\Delta y = \frac{\lambda L}{d}$$



Analyzing Double-Slit Interference…

What is the *fringe spacing* between the m fringe and the m+1 fringe?

$$\Delta y = \frac{\lambda L}{d}$$

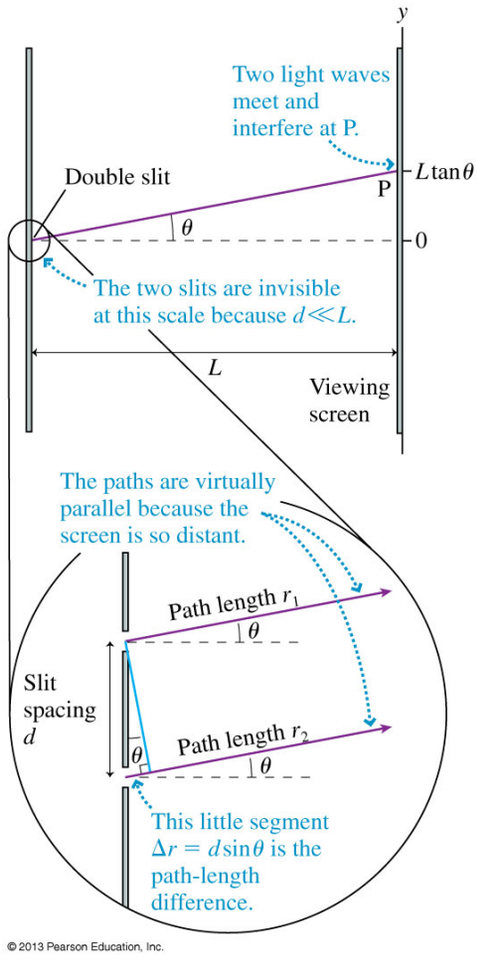


Notice:

The interference pattern is a series of *equally* spaced bright lines.

Analyzing Double-Slit Interference…

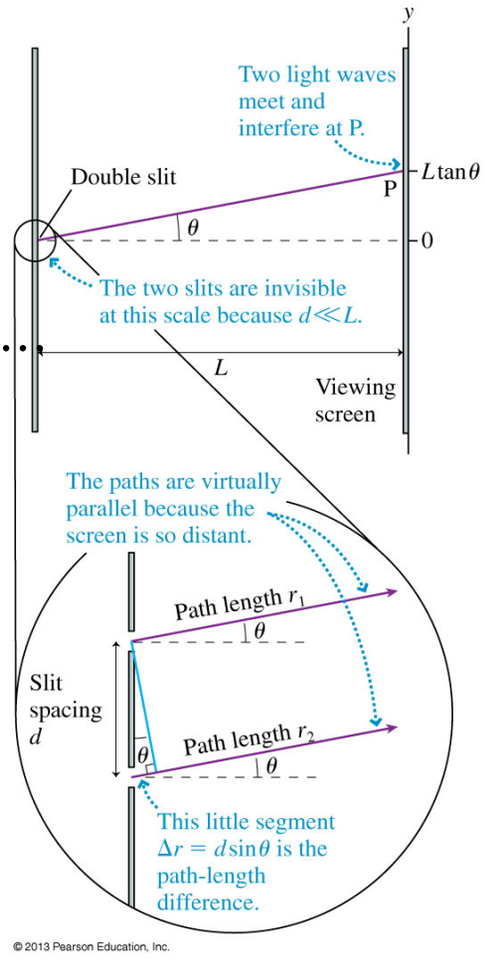
Where does the m^{th} *dark fringe* occur?



Analyzing Double-Slit Interference…

Where does the m^{th} *dark fringe* occur?

$$y'_m = \left(m + \frac{1}{2}\right)\frac{\lambda L}{d} \quad , \quad m = 0, 1, 2, 3, \ldots$$



Notice:

The *dark* fringes are located *exactly halfway between* the *bright* fringes.

helium $\quad \lambda = 6.33\times10^{-7}\,m$

$d = 4.0\times10^{-4}\,m$

$L = 2.0\,m$

$$y_m = \frac{m L \lambda}{d} = \frac{2(2.0\,m)(6.33\times10^{-7}\,m)}{4.0\times10^{-4}\,m} = 6.33\times10^{-3}\,m$$

$$\text{Gap} = 2(6.33\times10^{-3}\,m)$$

$$= 1.3\times10^{-2}\,m$$